



KN Physics at Low and Intermediate Energies

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List of contents

- 1. State of the field.**
 - 2. Recent hopes for progress: DEAR, KLOE, FINUDA.**
 - 3. Surprises at higher energies: Θ^+ , Ξ^{--} .**
 - 4. What we need to know to go further.**
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1. State of the field.

The season of systematic investigations of kaon - nucleon interactions suffered an abrupt ending around 1980, with the closing down of most of the machines and of the beam lines dedicated to this branch of hadronic physics.

Despite many valiant efforts to resurrect the field (the European Hadron Facility and KAON at TRIUMF, just to name the bravest), the few remaining kaon beam lines have been barely sufficient to keep hypernuclear physics alive.

So many of the statements on the successes of flavour SU(3) - just to mention one single case in the physics of the Standard Model - so abundant in particle physics textbooks are in reality based on a handful of old, low-statistics, low-resolution experiments that nobody would even think today of proposing to a selecting committee.

Of course kaon beams have problems not presented by pion beams (which indeed have continued to be in - relative - availability), but the physics to be performed with them can not be replaced by anything else.

It is enough to mention that, while $G_{\pi NN}^2$ is known to a few percent, uncertainties on G_{KNA}^2 and $G_{K\Lambda\Sigma}^2$ are at the levels, respectively, of about ten and thirty percent, not to speak of pion-hyperon couplings where standard dispersive techniques yield errors of order 100%!

Also, a cursory glance at the PDG tables shows that there are a lot of "missing" Λ and Σ states (not to mention the even more missing Ξ 's and Ω 's), which only an accurate PWA can uncover, given data of quality comparable to that of the πN ones.

→ Total cross sections

→ Phase shift analyses

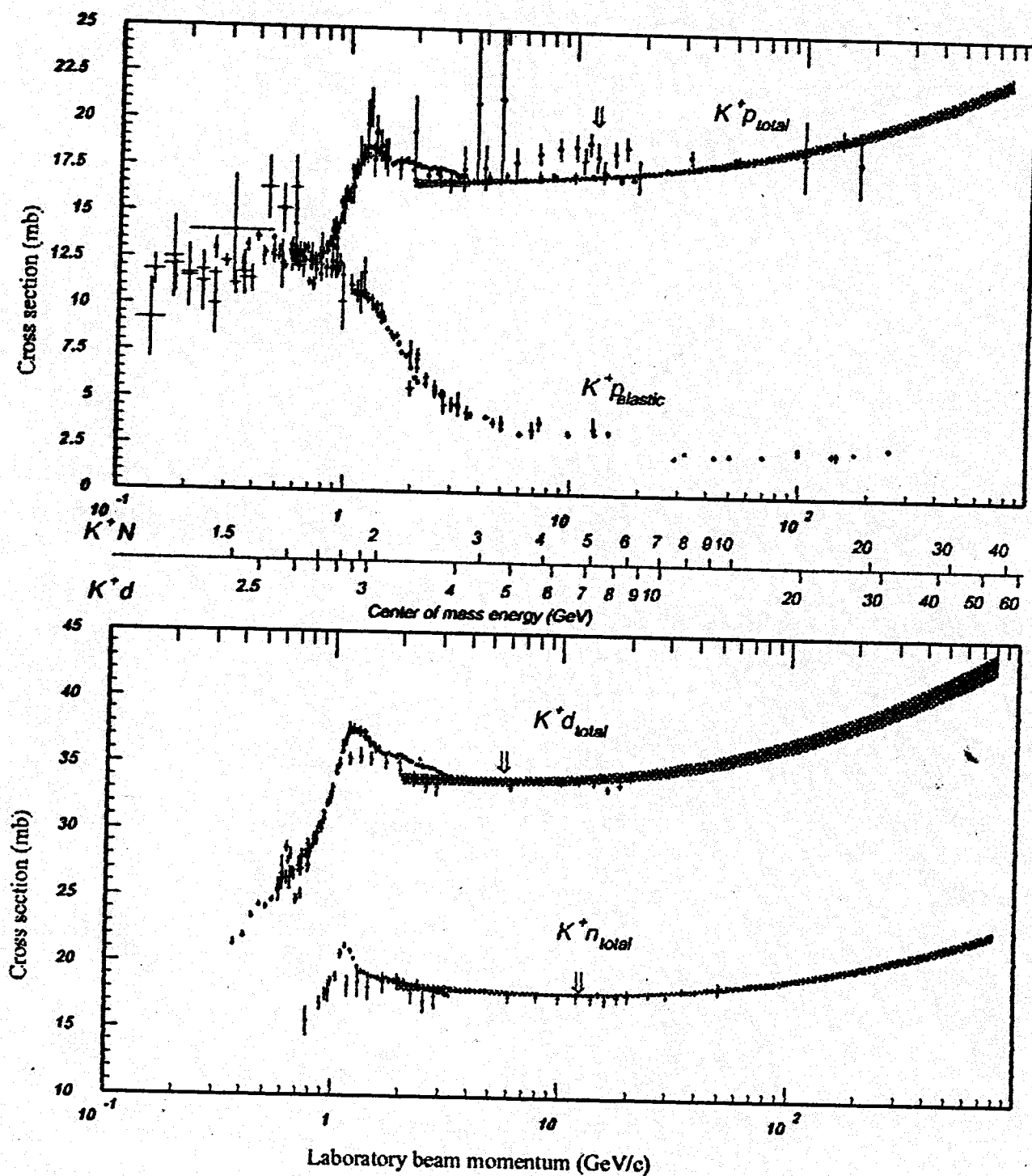


Figure 40.15: Total and elastic cross sections for K^+p and total cross sections for K^+d and K^+n collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at <http://pdg.lbl.gov/xsect/contents.html>. (Courtesy of the COMPAS Group, IHEP, Protvino, August 2003.)

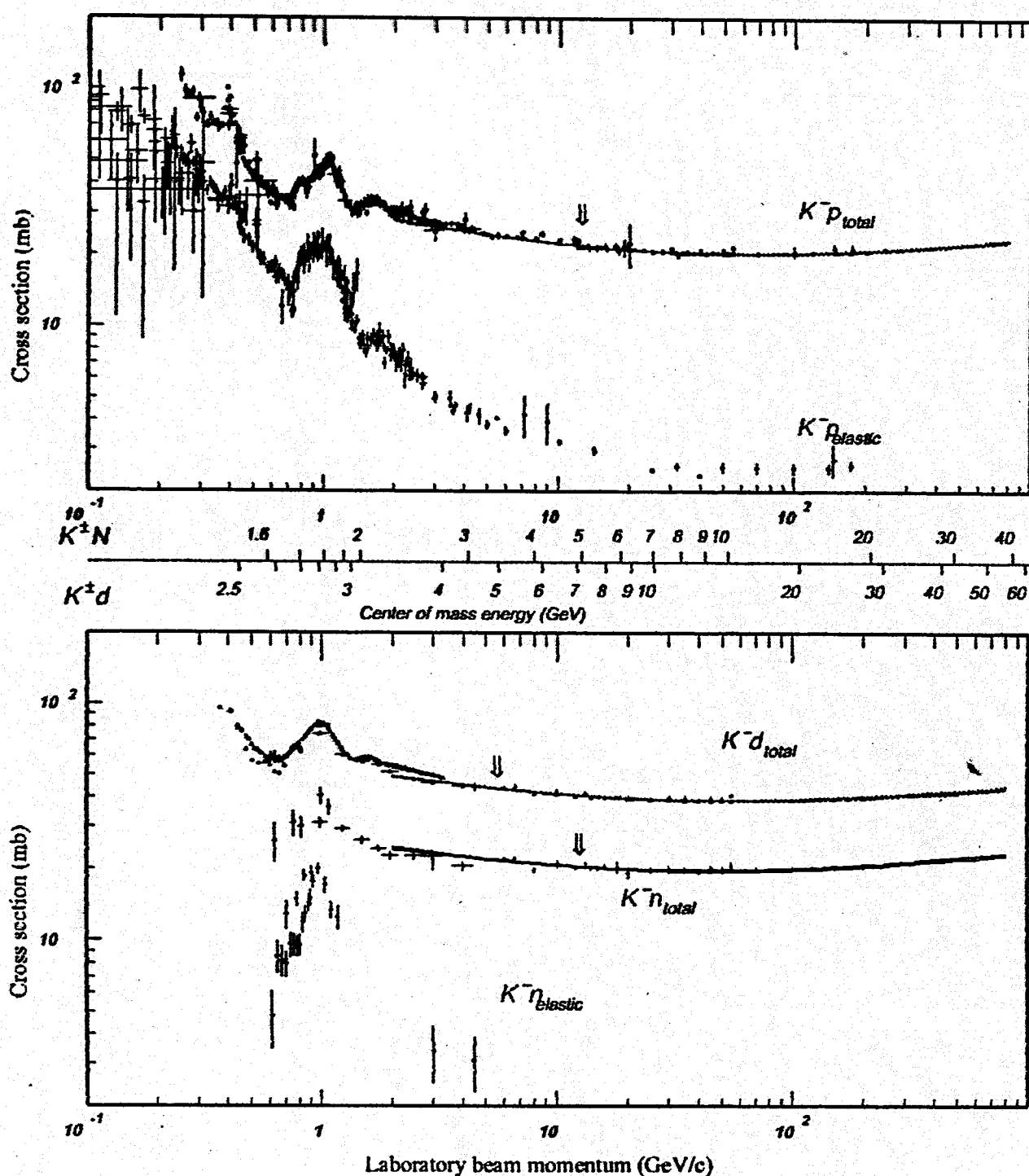


Figure 40.14: Total and elastic cross sections for $K^- p$ and $K^- d$ (total only), and $K^- n$ collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at <http://pdg.lbl.gov/xsect/contents.html>. (Courtesy of the COMPAS Group, IHEP, Protvino, August 2003.)

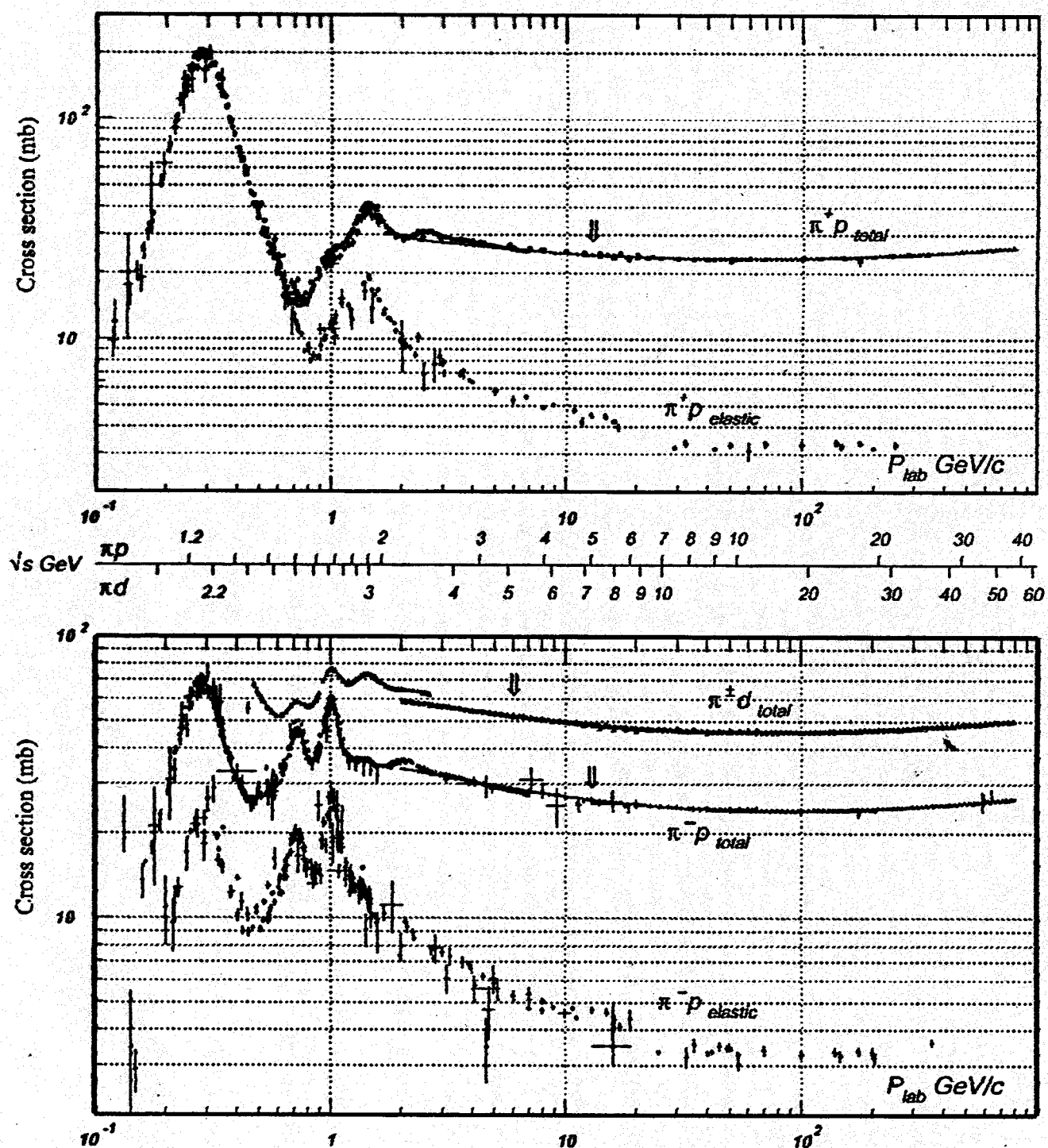


Figure 40.13: Total and elastic cross sections for $\pi^- p$ and $\pi^\pm d$ (total only) collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at <http://pdg.lbl.gov/xsect/contents.html>. (Courtesy of the COMPAS Group, IHEP, Protvino, August 2003.)

K^-N

very low energy: below threshold $\pi\Lambda, \pi\Sigma, \pi\pi\Lambda$

Kim analysis and Sakitt analysis (1965-1967)
using formalism developed by Dalitz & Tuan
and PWA until 400 MeV/c
find Λ (1405) and Σ (1385)

This gives confidence on the formalism, but
does not improve quantity and quality of data

in intermediate energy: Gupta (includes up
to F-waves, but does not reproduce structure
below threshold)

πY interaction

"Known" via $\bar{K}N$ phase shift coupled
channel analyses

Determination of $\pi\Lambda\Sigma$, $\pi\Sigma\Sigma$ couplings

Chan & coll. 1968-1970

Engels & Pilkuhn 1971

Merlani & GV (very high energy - Pomeron
coupling to $\pi\Lambda$)

Garsini & coll 1997 conventional d.r.
1998 rapidly convergent d.r.

K^+N

$I=1$ essentially s-wave at low energy

$$a_s = -0.3 f (\pm 3\%)$$

intermediate energy (1971)

Lea & coll. PWA some solutions

indicated a possible Z_0^*

$I=0$ small value of sc. length

intermediate energy

PWA Wilson et al (1972)

$Z_0^* ?$

indication in some solutions

$$M \sim 1800 \text{ MeV} \quad P \sim 300 \text{ MeV}$$

elasticity 0.85

(however, the peak observed in σ_{tot} was at slightly lower energy)

$$K_L p \rightarrow K_S p$$

the information is equivalent to

$$K^- n - K^+ n$$

Wignol 1967

Atkin 1980 calculation of $g_{N\pi K}^2 = 2.7 \pm 0.9$

2. Recent hopes for progress: DEAR, KLOE, FINUDA.

In a kinematical range not available to conventional beam - target experiments, ϕ -factories such as DAΦNE in Frascati can prove invaluable, being sources of almost monochromatic K^+ , K^- and K_L of about 100 MeV/c.

Already, the DEAR experiment has presented results solving the long-standing puzzle of the $K_{\alpha,\beta}$ lines of kaonic hydrogen (the shift is, as almost everybody but a few expected, repulsive), and gone along with a good program of other kaonic atom studies.

On the other side of the double-ring machine, KLOE, while doing her job of collecting neutral kaon decays looking for the tiny effects of CP violation, and in the meanwhile also reaping a good harvest of more conventional hadronic physics (cross sections, radiative decays, etc.), has collected many tens of thousands of interactions of the kaons with the helium filling her huge wire chamber which sit in her PC's waiting only to be analysed.

In the meanwhile, FINUDA has started collecting data on hypernuclei, taking the place formerly occupied by DEAR. The design of FINUDA should also allow the observation of some kaon-nucleon interactions, and in particular the collaboration plans to take data on charge-exchange of K_L 's on the hydrogen of the plastic scintillators.

Clearly the energy limitation of ϕ -factories (kaons can be slowed down but not accelerated in the detectors) makes them complementary to beam - target experiments, where kaons have to be transported from the primary target to the apparatus, and have to be energetic enough in order to survive the trip, however short.

3. Surprises at higher energies: Θ^+ , Ξ^{--} .

The last year has seen a frantic activity, both experimental and theoretical, in trying to confirm and understand an $S = +1$ KN state around $1540 \text{ MeV}/c^2$, re-named the Θ^+ (a.k.a. Z^+ to those old enough to know what a slide rule is).

Since such a state is the "tip" of a 10^* representation of $SU(3)$ - same as a 10 but upside-down - and a search for its partners has obliged us in producing a candidate for the strangest of them all, a doubly charged, negative Ξ , a step to be taken would be a PWA of the $I = 0$ KN channel to look for its further confirmation and to pin down its J^P .

The old experience with the quest for the Z^+ (now you see it, now you don't) has taught us that such an analysis will be fruitless unless statistics and energy resolution are high enough and that one needs to have both K^+n and K_Lp , not only as an independent check but also to reduce the dependence on theoretical assumptions about the deuteron wavefunction.

4. What we need to know to go further.

The experience lived by the particle physics community when presented with an $S = +1$ full-fledged "exotic" - which, according to folklore, should not have been there in the first place (do you remember old-time duality?) - should teach us that systematic, painstaking, careful investigations do pay up in the end (remember atomic physics and the birth of QM) even if you don't get invited to Stockholm.

Since an adequate understanding of strong interactions implies also an understanding of the role of flavours beyond simple "counting rules", it would be a waste of time and/of resources if a program at a hadronic beam machine capable of producing intense kaon beams did not include at least in part a program of systematic investigations of both $S = +1$ and -1 KN channels with statistics and resolutions comparable to those available at pion factories.